Artificial Refrigeration.

CARRÉ'S

AND

MIGNON & ROUART'S

CONTINUOUS FREEZING APPARATUS

For the production of ICE by the direct action of Heat.

MANUFACTURED BY

M. J. BUJAC,

Office, No. 17 Broad St., Post Office Box 2803, New York.

The only industry producing a necessity in which the raw material (water,) costs nothing.

Gold and Prize Medals and First Premiums invariably awarded to these Apparatuses at the London, Paris and other European Fairs.

PHILADELPHIA:
INQUIRER BOOK AND JOB PRINT, 304 CHESTNUT STREET.
1870.

Fig. 1.

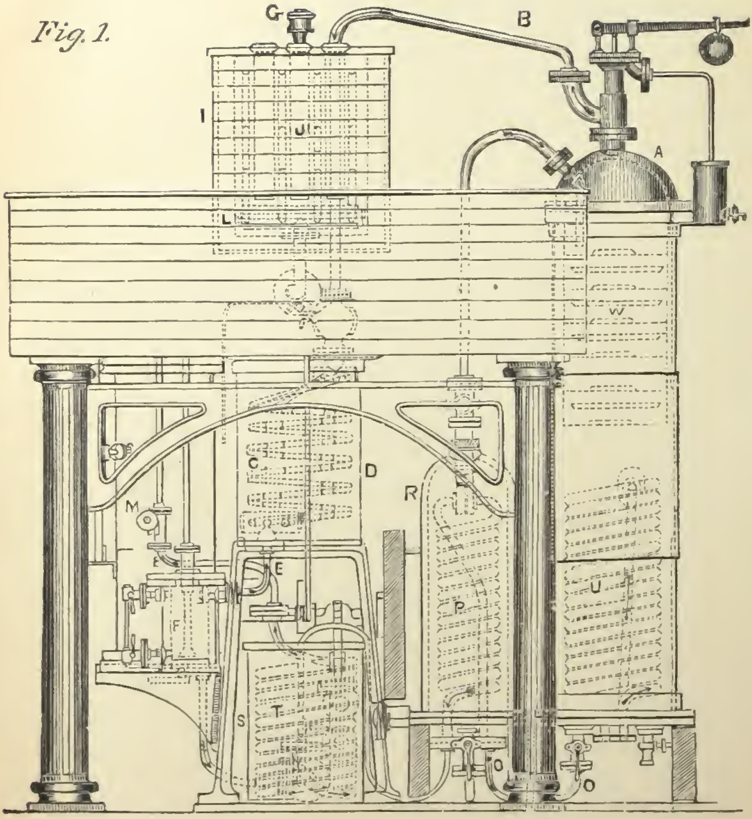


Fig. 3.

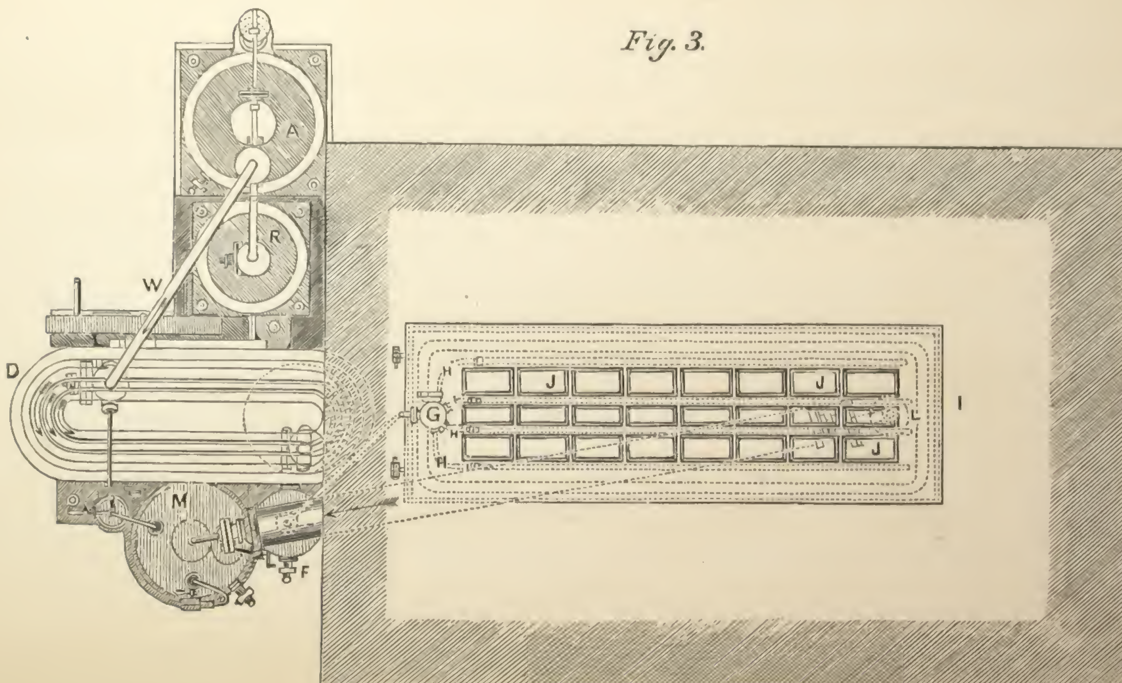
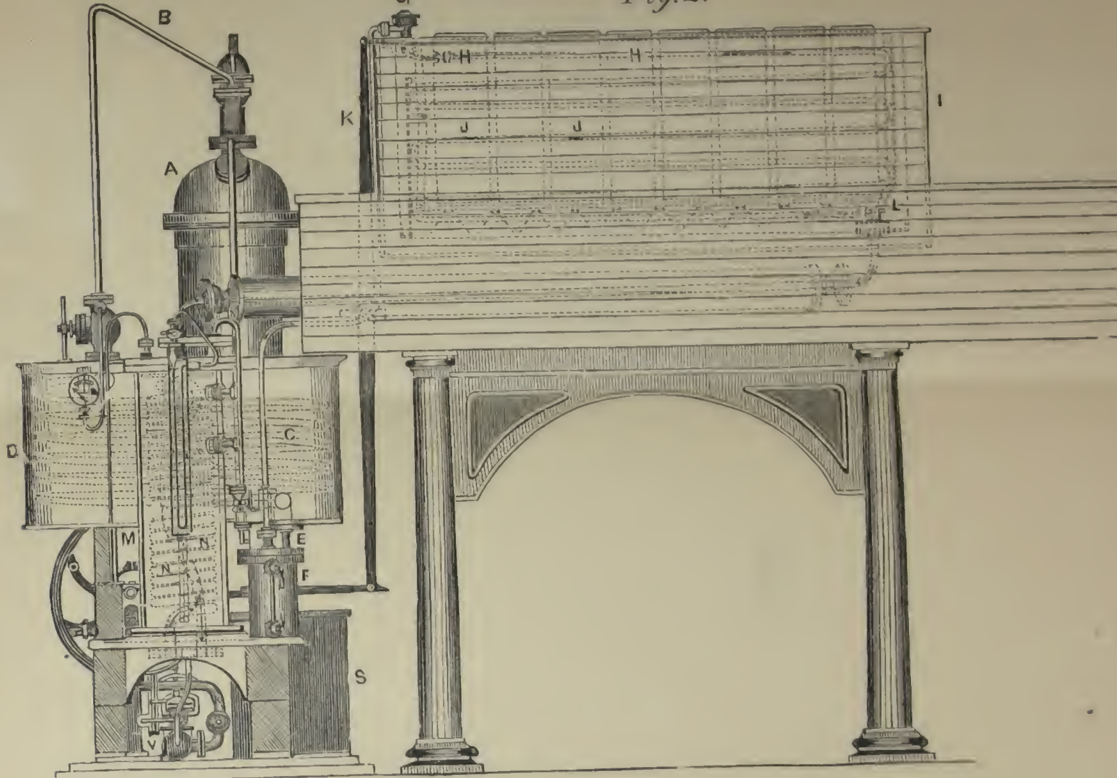


Fig. 2.



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ARTIFICIAL REFRIGERATION.

BY M. J. BUJAC.

Artificial refrigeration is now assuming such an important place in the arts that, without entering into all the details of its history, it is nevertheless proper to review the principal and most important attempts made by inventors to bring it to its present state of perfection.

The processes employed may be divided into three classes:

1st. Specific heat.

2d. Latent heat of fusion.

3d. Latent heat of volatilization.

I.—APPARATUS EMPLOYING SPECIFIC HEAT.

These contrivances are generally very limited in power. They are founded on the fact that two bodies, liquid or gaseous, at different temperatures, when brought into communication with each other, whether at a distance or by contact, exchange their temperatures.

It is a well known fact that ice has been manufactured in Bengal by utilizing the clearness of the sky, the evaporation of water, and the non-conductibility of straw.

Exchanges of Temperature.—The exchange of specific heat by contact is more frequently employed, and without entering into comments upon the details of the various refrigerating processes applied in domestic use, which seem to be daily accomplished as if by instinct, some allusion should be made to exchanges of temperatures employed in breweries, distilleries, &c.

The exchanges of temperature are almost always employed between two liquids. The rudimentary form of the apparatus is that of a worm, of which the section is annular. In the inner portion a liquid, which is originally supposed to be hot, is circulated, and in the annular worm a cold liquid is forced through. They flow in opposite directions, so that by prolonged contact their temperatures equalize, the hot liquid having heated the cold. If any account is taken of the difference of density created by expansion, common sense will show that the apparatus being placed vertically, the liquid which is being heated should rise from the bottom to top; by properly inverting such an arrangement, the effect produced of an exchanging surface in many cases may be considerably decreased.

The theory of this system of apparatus is very simple; it illustrates the fact that several units of heat given out by the hot liquid is equal to the same number of units absorbed by the cold liquid; and this gives the measure of their power.

Compressed Air Apparatus.—Specific heat has likewise been employed in other more complicated machines, which have brought out several patents, the combinations of which are extremely ingenious while experiments have been numerous, but very costly.

The inventions just alluded to employed either compressed atmospheric air or incondensible gases. They are founded on the well known laws of physics, that, compression producing heat, expansion must, by inversion, produce cold. The quantity of heat developed by the compression of an incondensible gas is frequently very great. We have all seen punk take fire in the air syringe. On the other hand, when atmospheric air escapes rapidly from a reservoir where it has been sufficiently compressed and cooled, it will condense a part of the humidity

of the surrounding atmosphere into snow. To apply these properties to industrial use, atmospheric air compressed by large pumps has been cooled by a current of cold water running around it, and then expanded in contact with substances to be frozen.

M. Peclet, a French physicist of some note, estimates that one horse power would produce, theoretically, 75½ English pounds of ice per hour. This would be a good result, though inferior to those since obtained. M. Peclet neither took into consideration the loss expended in power nor the bad conductibility of gases, which were probably the main cause of the inferior producing capacity of the apparatus.

Atmospheric air and incondensible gases give out either heat or cold communicated to them with great difficulty; it is almost impossible to take away from atmospheric air the high temperature communicated to it by compression, or to collect cold which it has obtained by expansion.

One of the first and most complete arrangements of this kind was invented by Dr. John Gorrie, of Florida, who obtained a patent in England, in the name of his solicitor, Wm. E. Newton, in 1850. He collected heat by means of divided sprays of water injected by a pump; to collect the cold, he replaced the water by an uncongealable liquid, such as spirits, brine, &c. Up to the present this system of apparatus has produced unsatisfactory industrial results. Kirk, in 1862, invented machines on the same principle. The last inventor put up apparatus at the Bathgate Paraffin Works, in Scotland, where the equivalent of "one ton of ice" was produced by consuming "one ton of coal."

II.—APPARATUS EMPLOYING LATENT HEAT OF FUSION.

The employment of the properties of latent heat of fusion, which is greater than specific heat, for equal variations of temperature, has nearly always given more satisfactory results.

Quite a number of machines have been invented and constructed for the purpose of rendering these properties useful, the most practical of which were patented.

The first to which allusion is made are those which are based on the employment of latent heat, as a body passes from a solid to a liquid condition. Each body requires a given quantity of heat to melt it: it is therefore evident that if two solid bodies are mixed together, the reciprocal action of which makes them melt, it may happen that the required units of heat for melting may be more numerous than those supplied from the substances in contact, or from the surrounding bodies. The same phenomena occur between a solid body which is simply dissolved in a liquid. In this manner refrigerating mixtures are constantly used in apparatus of various shapes, generally comprising a reservoir containing the substance to be frozen, surrounded by another reservoir or vessel, inclosing the refrigerating mixture, which is covered by a non-conducting substance, to protect it from the external heat.

The most commonly employed refrigerating mixtures are the solution of nitrate of ammonia in water, which lowers the temperature from 48° to 7° above zero, Fahrenheit; the mixture of sulphate of soda and hydrochloric acid, which will reduce the temperature from 48° to 3° above zero, F., and the mixture of ice and salt, which are daily employed in domestic use. Although these systems of apparatus have been so frequently put into use, they have not yet developed into important industries. An attempt which should not pass by unno-

ticed, although it has shown no industrial results, was patented in England, in 1855, by Siemens. It had the merit of being presented in a most ingenious manner. He proposed the continuous manufacture of ice by means of a refrigerating mixture obtained by a body dissolving and concentrating itself continuously. For example, around a freezing cistern of any convenient form water was placed, into which nitrate of ammonia was made to fall, thus causing a lowering of temperature to about 15° above zero, Fahrenheit. When the solution was made, and the effect produced by the cold exhausted, the liquor was run off, and was replaced by water and solid nitrate of ammonia. The nitrate of ammonia was re-obtained by evaporating the solution, which evaporation was continued until the material became perfectly solid and dry. This attempt likewise seems to have failed; it must have met with many serious difficulties in its practical execution.

III.—APPARATUS EMPLOYING LATENT HEAT OF VOLATILIZATION.

The future art of artificial refrigeration seems to rest on the application of the properties of the latent heat of volatilization. The machines which are based on its application may be divided into two classes:

1st. Those founded on Leslie's experiments.

2d. Those founded on Faraday's experiments.

To commence with the first class it is necessary to recall to memory Leslie's two well known discoveries.

Place upon the platform of the air pump a capsule, full of ether, into which a bottle containing water is plunged; then produce a vacuum, and in a very short time the bottle will burst, because the water it contained is frozen. Replace the capsule which contained ether by another containing sulphuric

acid, and above the capsules have a platform on which there may be a few drops of water; then obtain a vacuum, and the water will freeze very rapidly.

These two experiments were so conclusive that they became the starting point of numerous attempts from which apparatus of various forms were constructed, differing from each other as they inclined toward either of the above mentioned experiments.

Jacob Perkins, an American, patented in England, in 1834, an apparatus, the fundamental principle of which was based on Leslie's first experiment. He described in his patent a freezing cistern, or inclosed vessel, containing liquid ether, or some other condensed gas, in combination with an exhausting and compressing pump, and a condenser or restorer. This pump in its alternate movements successively exhausts the vapor of ether, which volatilizes in the freezing cistern, and afterward compresses it into the condenser or restorer, where it is restored to its original liquid condition.

It is perfectly well known that the change from a liquid to a gaseous state is only effected by absorbing from the surrounding objects a number of units of heat, which represent its latent heat. Therefore the ether in such a case is only in contact with itself and with the bodies which are to be acted on. Not finding in its own substance sufficient caloric to absorb, it will borrow heat from the bodies surrounding it; of which it necessarily reduces the temperature.

The apparatus of Perkins seems to have served as a basis for improvements made in the art of refrigeration by the following inventors: Bourgois, Kingsford, Harrison, Carré, Siebe, Tellier, Mort, Nicolle, Lowe, Vanderweyde, and others. Although the fundamental principles of this system are very simple, their practical effects present many serious difficulties

to be overcome. The apparatus must be constructed with great care and attention, and out of materials almost indestructible. The smallest openings through which the gases or vapors might escape, or the atmosphere enter, must be studiously avoided, atmospheric air being the eternal enemy of easy and normal condensations or volatilizations. Above all it is the influence of insensible apertures that is to be feared, for it is that enormous influence which forcibly limits the power of the apparatus; in fact, when the tension of the gas of ether is reduced an inch or two of mercury, the vacuum produced by the action of the piston is destroyed by the volatilization of the condensed vapors which accumulate under the lid of cylinder.

The rapid wear of the apparatus is likewise to be apprehended. For instance, the cylinder and body of the pump, which are originally fitted to each other with great care and at enormous expense, *invariably wear out of shape after the apparatus has been a short time in operation, and these defects finally allow the gas to pass from one side to the other of the piston, thereby causing a loss of vacuum, which destroys a considerable amount of working power.*

Many ingenious physical and mechanical operations, based on Perkins' patent, have been tried, but in most instances have *failed* to realize the sanguine expectations of the inventors.

Sulphuric ether, which was the material at first employed, has since been partially replaced by protoxide of nitrogen, sulphurous and carbonic acid gases, carburet of hydrogen, gasoline, chimogene, methylic ether, &c., &c.

Carre, like other inventors, employed ether as his freezing agent, in apparatus patented in Europe and America from 1857 to 1860, which required the use of "powerful steam machinery," in combination with "exhausting and compressing pumps." Although he

manufactured ice on a commercial scale, he was compelled to abandon his invention, after having expended large amounts of money on it, and resorted to his new system, with which he produced such wonderful results.

Peclet describes an apparatus in which he employs simultaneously vacuum and the absorption of the vapors of water by chloride of calcium; its fundamental principles seem to have been taken from Leslie's second experiment.

Other machines have been constructed, which literally reproduce the last mentioned experiment. The air pump is employed to produce vacuum, and sulphuric acid as the absorber. These inventions present the same objections as those based on Leslie's first experiment, and taking everything into consideration they must be more complicated, because they employ the two agents of vacuum, namely the pump, and the powers of affinity.

CARRE'S APPARATUS.

The machine that up to the present day has attained the greatest industrial perfection, and from which the most useful results have been obtained, was invented by Carré, and is based on Faraday's experiments. The idea which distinguishes it from all others is the "*production of vacuum and of volatilization by the action of affinity alone.*"

It merely requires a few words to recall to our minds the experiment which served as a starting point. The illustrious Faraday studied the properties of various gases which were considered non-condensible, and succeeded in liquefying a great number of them under the double influence of pressure and cold. His process, which was very simple, consisted in the employment of a very strong glass ∩ shaped tube. In one of the branches of this tube, he inclosed a body, which un-

der the influence of heat, could separate from it the gas which he wished to experiment with; he kept the other limb in a refrigerating mixture; he inclosed very dry chloride of silver in his tube, which had already absorbed large quantities of ammoniacal gas. He heated the first limb of the tube, and in a short time obtained in the second branch a liquid, which was liquefied ammoniacal gas. By leaving the tube under its own influence, he observed that it gradually cooled off, and that while it was cooling the ammoniacal gas volatilized and went back to be reabsorbed by the chloride of silver; he merely remarked at the same time that as volatilization took place, the ammoniacal gas produced very intense cold.

There are few examples which demonstrate in such a striking manner the slow progress of the human mind, for it required upward of thirty years before any inventor ever thought of applying this remarkable experiment to use. Probably it was because Faraday's complete experiments are very seldom illustrated by lecturers; his tube is at times shown to students, but very seldom experimented with, because it must be handled with extreme care.

Nevertheless, M. Carré founded on Faraday's observations a most ingenious and remarkable apparatus, afterward improved upon by his associates, Messrs. Mignon and Rouart. Ammoniacal chloride of silver being considered too costly as a freezing agent, was replaced by concentrated aqua ammoniæ.

The following description of M. Carre's process, lately put in successful operation in Philadelphia, is from the *American Journal of Pharmacy*:

"Mr. Carré's invention consists in the use of ammoniacal gas, liquefied by pressure, as his agent for freezing water, which it does by abstracting and rendering latent the heat of the water necessary to its liquid condition. The manner of using the ammonia to effect this purpose is exceedingly ingenious, and apparently paradoxical, inasmuch

as '*heat is applied to produce cold;*' '*fire to make ice;*' and this is one of the claims of originality made by the patentee, who also claims '*the application of the power of absorption due to mutual affinity as a means of producing vacuum, volatilization, the removal of heat, and the consequent production of cold*'' It may be premised that the form of ammonia used is the concentrated aqua ammoniæ, containing 26 per cent· of gaseous ammoniæ, and that there is a constant pressure in the apparatus, when in full operation, varying from 8 to 13 atmospheres, equal to about 120 to 200 lbs to the square inch.

"The apparatus consists (1) of a cylindrical, dome-topped, vertical *boiler*, *A*, into which the aqua ammoniæ is introduced, part of which enters the exchanger, the complement and the absorption vase, to be described. A large tube *B*, issuing from the dome connects it with (2) the *liquefactor*, *C*, which is an extensive series of connected tubes, nearly horizontal, contained in a sheet-iron tank *D*, filled with cold running water. In this the gas, under the great pressure and the cold, is liquefied, its latent heat being carried off by the cold water, whilst the liquid ammonia passes out at the lowest end by a small tube *E*, into (3) the *recipient*, *F*, where it collects. This vessel is connected by a tube with (4) the *distributing valve*, *G*, which distributes the liquid ammonia, by means of four small tubes of 1-16 of an inch calibre, into four stacks of zig-zag tubes *H*, contained in the *freezing cistern*, *I*. The freezing cistern consists of a wooden tank lined with iron, in which are placed four lines of vertical zig-zag tubes, above noticed, into which the liquefied ammoniacal gas enters from the distributing valve. Between these tubes, twenty-four meta lic cans, or freezers, filled with water, are placed, and the whole interior of the tank is filled with a bath of strong brine, or, preferably, solution of chloride of calcium, which is incapable of being frozen by the temperature produced, and is made to circulate between the tubes and freezing cans *J*, as a carrier of heat, by a stirring apparatus *K*. These stacks of zig-zags connect at bottom with a cylinrical tube called the *collector*, *L*. When now the distributing valve is partially opened, the liquefied ammoniacal gas is forced in due proportion into the zig-zag tubes, where it rapidly expands into gas by the assumption of the heat necessary for its vaporization from the surrounding brine, which in its turn abstracts the heat from the water in the cans, (by virtue of which only it can retain its fluidity), and thus converts it into ice, and accomplishes the chief purpose of the machine. But the apparatus, acting continuously, now gathers the resulting ammoniacal gas, redissolves it in the weak liquor of the boiler which it has previously abstracted and cooled, and then returns it to the boiler to be again deprived of its gas. This remarkable compound result is effected in this wise: The ammoniacal gas, after performing its office of rendering latent the sensible heat of the water, passes on, first to the *collector*, *L*, and from this through a tube, to the *absorption vase*, *M*, which consists of a cylindrical vessel enclosing a tall coil of tube *N*, through

which passes a constant current of cold water), and there, after the machine has been working some time, it meets with the exhausted ammonia liquor, by which it is rapidly absorbed, and which thus regains its original strength. The manner in which the weak ammonia liquor reaches the absorption vase *M*, and the regenerated liquor ammoniæ is returned to the boiler *A*, all of which has been effected under pressure varying from 8 to 13 atmospheres, is as fol ows: By a tube *O*, reaching from the bottom of the boiler, the latter is connected with the coil of the *exchanger*, *P*, which consists of a cylindrical iron vessel *R*, about 16 inches in diameter. The lower end of the exchanger coil *P*, is connected with the lower end of another coil in a similar vessel beside it, called the *complement*, *S*, the upper end of which complement coil *T*, enters the absorption vase *M*, at the top, and descends nearly to the bottom.

"At first the boiler, exchanger, complement, and absorption vase, are all charged with strong ammonia, but as soon as the heat from the boiler coil *U* has driven off sufficient gas to create strong pressure, the weakened hot ammonia liquor is forced from the boiler *A*, into the coil of the exchanger *P*, where it is partially cooled by the cold ammonia of the absorption vase *M*, which the pump *V* has forced into the cylinder of the exchanger *P*, ready to replace the weak liquor in the boiler *A*. The weak liquor is then perfectly cooled as it passes through the complement coil *T*, which is surrounded by cold water, and it (the weak liquor) enters the absorption vase *M*, rapidly absorbing the gas entering from the collector *L*, thus reproducing aqua ammoniæ. Simultaneously the forcing pump *V*, of the machine, is drawing the cool strong ammonia from the under stratum in the absorption vase *M*, and forcing it in the cylinder of the exchanger *R*, where, after performing its office of cooling the weak liquor and becoming itself heated, it passes into the boiler *A*, near its top, impinging on a series of porous diaphragms of metal *W*, suspended in the upper part of the boiler *A*, to facilitate the rapid separation of the gas a second time. Thus it is apparent that the same aqua ammoniæ may be used over and over again.

"At starting the machine, all the cans *J* are filled with pure water, and closely covered with wooden lids, and when, after four hours, they are completely frozen, the operator removes the ice, which is effected by simply dipping the cans momentarily in hot water, and then inverting them. The cakes of ice are uniformly rectangular, and as their temperature when removed is far below 32° Fahr., by simply moistening their surface they freeze perfectly to each other, and form solid blocks of ice of any required dimensions."

COMPARISON OF THE REFRIGERATIVE EFFECTS OF THE CARRE APPARATUS AND COMMON ICE.

By referring to the following tables, the immense economy

realized in producing cold "dry" air by artificial refrigeration, over low "humid" temperatures, obtained by the melting of ice, is most forcibly illustrated.

A No. 3 "Carré apparatus," the producing capacity of which is five pounds of ice per minute, constructed by Messrs. I. P. Morris & Co., at the Port Richmond Iron Works, Philadelphia, yielded the following wonderful results, a short time ago, in presence of Professors Morton, Booth, Tilghman, and other scientific men, who had been invited to witness its operations.

The temperature of a closed room, measuring 3,375 cubic feet, was raised to 80° Fahrenheit by means of a stationary steam heater placed in it. A blower commenced to force cold air into this room from the refrigerating apparatus.

Time.				Deg's.	
At 1.20	when	the thermometer	stood at	80	Fahrenheit.
" 1.21	"	"	"	76	"
" 1.22	"	"	"	66	"
" 1.23	"	"	"	58	"
" 1.24	"	"	"	53	"
" 1.25	"	"	"	50½	"
" 1.26	"	"	"	48	"
" 1.27	"	"	"	46	"
" 1.28	"	"	"	45	"
" 1.29	"	"	"	44	"
" 1.30	"	"	"	43	"
" 1.31	"	"	"	42	"
" 1.32	"	"	"	41	"
" 1.33	"	"	"	40	"
" 1.35	"	"	"	39	"
" 1.37	"	"	"	38	"
" 1.40	"	"	"	37	"
" 1.44	"	"	"	36	"
" 1.47	"	"	"	35	"
" 1.56	"	"	"	34	"
" 2.05	"	"	"	32	"

During the trial, two glasses, one containing cold, and the other hot water, were placed at the opening of the inlet which conveyed the cold air into the room; the contents of the first were frozen to three-eighths of an inch thick in twelve minutes, while it required but twenty-three minutes to effect the same result with the latter, which had originally been at 140° Fahrenheit.

At the close of the operation, the thermometers of the cool-

ing box indicated fully as low temperatures as at the commencement, proving conclusively that the apparatus could indefinitely produce the same results. It is worthy of note that the steam heater was likewise cooled down to the temperature of the room.

The total amount of steam employed to supply heat, motive power, and water for the operation, was equivalent to less than five horse power.

On the following day the same room was heated to 80° Fahrenheit, and the temperature then lowered to 46° Fahrenheit by melting Portland ice.

The results obtained were as follows:

	Time.								Deg's Fahr.
At	2.34	when	1,054	lbs of ice	were on	the scales	the temperature	was	80
"	2.36	"	1,045	"	"	"	"		78
"	2.38	"	1,038	"	"	"	"		70
"	2.39	"	1,029	"	"	"	"		67
"	2.43	"	1,024	"	"	"	"		62
"	2.46	"	1 018	"	"	"	"		59
"	2.51	"	1,012	"	"	"	"		56
"	2.58	"	960	"	"	"	"		52
"	3.05	"	948	"	"	"	"		49
"	3.15	"	935	"	"	"	"		48
"	3.22	"	920	"	"	"	"		48
"	3.25	"	907	"	"	"	"		47½
"	3.30	"	900	"	"	"	"		47
"	3.46	"	880	"	"	"	"		46½
"	3.56	"	868	"	"	"	"		46½
"	4.32	"	815	"	"	"	"		46¼
"	4.58	"	760	"	"	"	"		46¼
"	5.00	"	754	"	"	"	"		46

At this last point it would have required such an increased quantity of ice to lower the temperature that the experiment was abandoned.

This last trial shows a loss of 300 pounds of natural ice to duce the temperature of a room from 80° to 46° Fahrenheit in two hours and twenty-six minutes, which effect in the first trial had been obtained by Carré's apparatus in seven minutes, with the same quantity of cold required to form thirty-five pounds of ice; thereby showing that *eight times as much ice* was consumed to produce the same quantity of cold air as was supplied by the apparatus.

In both instances the room was placed under identical conditions for the comparative tests, the outside temperature having been perfectly excluded.

It is therefore evident that the Carré process, properly applied to industry, must entirely supercede the old system heretofore employed of melting ice to reduce temperatures in such establishments as *breweries, packing and fruit houses, oil, paraffin, salt and chemical works*, and in other industries too numerous to mention; also, for *cooling, disinfecting and purifying the air in ships, hospitals, theatres, hotels, public buildings, &c., &c.*

From the above data, it may be safely calculated that Carré's *Large and Medium Sized Apparatus can yield for from twenty to thirty cents the same quantity of dry cold air as is given out by melting one ton of natural ice.*

Commercial and Industrial Advantages of the Carre and Mignon and Rouart Continuous Freezing Apparatus.

In Carré's system, "*the law of affinities is all powerful;*" *it disdains the* ter *invention of immense exhausting and compressing gas pumps, which necessitate the aid of powerful steam engines and boilers*; and nevertheless, thus reduced to its *own* powers, it produces *effects far superior* to those obtained by the absorbing power of vacuum.

The commercial and industrial success of these Apparatuses, is now fully illustrated at the works of the Louisiana Ice Manufacturing Company, above New Orleans, where six Number One Machines produce an average of from 72 to 76 tons of ice per 24 hours, at a cost of $3 per ton.

The regular *monthly* production of these six Machines is greater than the "*total*" *quantity of artificial ice obtained during the last* "*25*" *years from the apparatus of* "*all*" *other inventors.*

The Number One Apparatus', now constructed at the Port Richmond Iron Works, of Messrs. I. P. Morris & Co., Philadelphia, are so simplified that they are calculated to produce from "*eight*" *to* "*ten*" *pounds of solid ice for* "*one*" *cent.*

No steam machinery is more durable, nor can any be found to work with more accuracy and regularity than these improved machines.

With *one* pound of coal they produce from "*eight*" to "*twelve*" pounds of solid ice.

It is a "remarkable fact" that by Carré's process artificial ice is produced and sold at New Orleans at half the prices that natural ice can now be bought for in New York or any other city south of it. The manufactured article is equally as good as that imported to New Orleans; it is as pure as the water it is made from, and being perfectly healthy, seven-eighths of the entire population of that city consume it for drinking purposes.

The cost of the Carré apparatus', when compared with their "*real*" *and* "*regular*" *production*, is far less than the price of any other apparatus in existence.

By referring carefully to this pamphlet, every chemist and physicist will soon conclude that the "only" really "*practicable and industrial* refrigerating process thus far discovered is due to the genius of F. P. E. Carré."

The material employed in this process being aqua ammoniæ, "*a fire extinguisher,*" brewers pork packers, and other manufacturers may introduce these machines into their establishments *without fear of vitiating their policies of insurance.*

Ice and Refrigerating apparatus for industrial purposes can be constructed on six or eight weeks' notice by applying to

M. J. BUJAC,

P. O. Box 2803, *New York City.*

July 1*st*, 1870. *Office*, *No.* 17 *Broad Street.*